International Classification H 011

Federal Republic of Germany

German Patent Office

Patent Application 1 105 525

S 66456 VIIIc/21g
Date of Application: December 29, 1959
Date of Registration:
And Release of Application: April 27, 1961

Semiconductor assembly

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Because of their sensitivity semiconductor elements with pn-junction coatings in single crystalline semiconductor bodies, for example, those made of germanium or silicon, must be enclosed in a housing that is evacuated or filled with shielding gas. It is customary to use soft solder to connect semiconductors that have been assembled complete with their electrodes to a surface of the housing, e.g., to its floor. Because the housing must dissipate the heat loss of the semiconductor element, it is generally manufactured of copper with appropriately sized wall thicknesses while the soldered-on electrode plate of the semiconductor element generally consists of a material that has a low thermal expansion coefficient, such as molybdenum or tungsten.

The subject invention relates to a semiconductor assembly in which an electrode plate of the semiconductor element is connected by soft soldering to a surface of a metallic component, which has a different thermal expansion coefficient than that of the contiguous electrode plate. In the invention the mentioned component is provided with a soft-soldered coating to which the semiconductor element is connected by means of soft soldering and the thermal expansion coefficient of the coating is located between those of the component and the electrode plate such that the mechanical stresses that develop in the soft solder layers during temperature changes are significantly reduced. Therefore, what the subject assembly achieves is that the soft solder coatings lie contiguous to components whose expansion coefficients show a significantly smaller difference than do the expansion coefficients of the metallic component, such as the floor of the copper housing and the contiguous electrode plate of the semiconductor element. The interior stresses which occur in the soft solder layers during temperature changes are therefore significantly reduced. The result is that the durability of the soft solder layers and thereby the life of the entire assembly is considerably increased. The subject assembly is primarily significant for those semiconductor assemblies that are particularly thermally stressed because of frequent on-and-off switching, for example, for vehicle and welding rectifiers. The stress that the soft solder coating undergoes during temperature changes may also be further reduced by providing the metal component, for example, the housing floor with several layers of soft soldered coatings whose thermal expansion coefficients are incrementally varied between those of the component and that of the electrode plate.

In a silicon rectifier that is structured as described

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above, the expansion coefficient of the housing copper is $a = 16.5 \times 10^{-6} \times$ grad-^{1}, while that of the electrode plate made of molybdenum or tungsten is $a = 5 \times 10^{-6} \times$ grad-^{1}. Especially chromium (expansion coefficient $a = 8.5 \times 10^{-6} \times$ grad-^{1}), platinum ($a = 8.9 \times 10^{-6} \times$ grad-^{1}), palladium ($a = 10.6 \times 10^{-6} \times$ grad-^{1}) and gold ($a = 14.2 \times 10^{-6} \times$ grad-^{1}) are potential materials for coatings that have intermediate thermal coefficient values. Plates made of iron-nickel alloys may also be used for the same purpose. By varying their compositions the thermal expansion coefficient of such alloys may be changed and/or adjusted over a wide range. Also, pure iron ($a = 11.5 \times 10^{-6} \times$ grad-^{1}) and pure nickel ($a = 12.5 \times 10^{-6} \times$ grad-^{1}) may be considered for use. Iron, nickel and their alloys present, however, a certain disadvantage in that they experience increased eddy current losses due to their ferromagnetism. However, this effect is insignificant in plate thicknesses of up to approximately 1 mm.

The subject assembly is important mainly because of the connection of a pn-semiconductor element to the floor of its housing; however, the assembly may, with equal advantages, also be used for connecting a flexible power supply lead to an electrode of such an element.

The following explains the invention with the assistance of figures 1 and 2.

Figure 1 shows a conventional silicon pn-rectifier, in which the thickness dimensions of the individual coatings are disproportionally exaggerated for ease of identification. The number 2 designates a single-crystalline silicon plate which is doped by a conventional method to produce a rectifying pn-junction. A thin aluminum coating 3 and a relatively thick molybdenum plate 4 are located on the bottom of the silicon plate 2, which may

also be coated with an iron-nickel alloy 5 to improve the soldering capability. On the top of the silicon plate **2** is a gold coating **6** and a molybdenum plate 7, which may also be provided with an iron-nickel plating **8**. The relatively thick molybdenum plates **4** and **7** have approximately the same thermal expansion coefficient (a = 5.1 x 10^{-6} x grad-^{1}) as the silicon plate **2** (a = 5 x 10^{-6} x grad-^{1}); accordingly, the entire element **1** behaves during temperature changes much like a unit body, because the thin intermediate layers **3** and **6** that are made of aluminum or gold do not create significant stress. Tungsten (a = 4.5 x 10^{-6} x grad-^{1}) may also be used for electrode plates **4** and **7**.

The essential parts of the entire semiconductor assembly are illustrated prior to assembly in figure 2. The rectifier element is again designated by the number 1. The housing of the element is designed as a thick-walled cup that is made of copper (a = 16.5 x 10^{-6} x grad-^{1}). The element **1** must be soldered to the floor **12** of the cup **10** as the assembly is being assembled; in addition, its upper electrode plate **7-8** must also be soldered to the copper base 14 of a flexible power supply lead 13. Since the semiconductor element **1** cannot tolerate very high temperatures, a soft solder is used which may be applied at temperatures of around 200°C.

In the subject assembly at least one spacer plate, whose expansion coefficient is between that of copper (a = 16.5 x 10^{-6} x grad-^{1}) and that of molybdenum (a = 5.1 x 10^{-6} x grad-^{1}. is provided between the rectifier element **1** and the floor **12** of the housing **10**. For example, a palladium plate, which has an expansion coefficient of a = 10.6 x 10^{-6} x grad-^{1} is suitable for this purpose. The embodiment of the invention provides for two spacer plates **20** and **21**, which, pursuant to the basic idea of the invention, have expansion coefficients in the proximity of 9 or 13 x 10^{-6} x grad-^{1}. For example, platinum (a = 8.9 x 10^{-6} x grad^{-1}) and gold (a = 14.2 x 10^{-6} x grad^{-1}) are suitable for this purpose. Iron-nickel alloys, whose composition is selected such that they have approximately the specified expansion coefficients, may also be used instead of the mentioned material.

In the completed assembly, which is illustrated at an enlarged scale in figure 1, are three soft solder coatings between element **1** and the housing **10**, each of which must absorb only one third of the stresses that occur during temperature changes and are attributable to the greater expansion of the copper between plate **4** and the housing **10**.

The base 14 may also be provided with two layers **22** and **23** which have expansion coefficients that correspond to those of the plates **20** and **21**.

The further assembly of the semiconductor assembly occurs then by a conventional method such that the copper sleeve **16** of the flexible power supply lead **13** is connected to the upper edge of the container **10** by means of metal-glass fusion, which is not illustrated. The interior space of the housing is then evacuated and sealed.

Layers **20**, **21**, **22** and **23** should not be too thin since they are not used to transfer the thermal expansion forces

from one soft solder layer to the next; on the other hand, layers that are too thick are also not desirable, because they lengthen the heat dissipation path between the semiconductor element and the housing. An overall thickness of between approximately 0.5 and 3 mm is recommended for layers **20** and **21** or **22** and **23** when the diameter of the rectifier element **1** is approximately 20 mm.

The invention was explained based on the structure of a silicon rectifier assembly... However, it may also be used for other types of semiconductor assemblies, for example, power transistors and other multi-layered semiconductor diodes or triodes.

PATENT CLAIMS:

1. Semiconductor assembly in which an electrode plate of a semiconductor element is connected by soft soldering surface-to-surface to a metal component that has a different thermal expansion coefficient than that of the contiguous electrode plate, characterized by the fact that (1) the mentioned component is provided with a soft soldered layer to which the semiconductor element is connected by soft soldering and (2) the thermal expansion coefficient of the layer lies between those of the component and the electrode plate such that the mechanical stresses occurring in the soft solder layers during temperature changes are significantly reduced.
2. Semiconductor assembly in which an electrode plate of a semiconductor element is connected surface-to-surface by soft soldering to a metal component which has a different thermal coefficient than that of the contiguous electrode plate, characterized by the fact that (1) the mentioned component is provided with several soft soldered layered coatings to whose upper layer the semiconductor element is also connected by soft soldering and (2) the thermal expansion coefficients of the layers are incrementally varied between those of the component and the electrode plate such that the mechanical stresses occurring in the soft solder layers during temperature changes are significantly reduced.
3. Semiconductor assembly according to claim 1, characterized by the fact that a plate of chromium, platinum, palladium, gold, iron or nickel is used as a layer.
4. Semiconductor assembly according to claim 1, characterized by the fact that a plate made of an iron-nickel alloy of suitable composition is used as a layer.
5. Semiconductor assembly in which the connection between the electrode plate of a single crystalline pn-semiconductor element and the floor of its housing is formed in accordance with claim 1 or 2.
6. Semiconductor assembly in which the connection of an electrode plate of a single crystalline pn-semiconductor element is formed with a flexible power supply lead in accordance with claim 1 or 2.

Attached hereto is one sheet of drawings

DATE OF ISSUE: APRIL 27, 1961
DAS 1105525
Classification 21 g 11/02
International Classification H 011

Figure 1

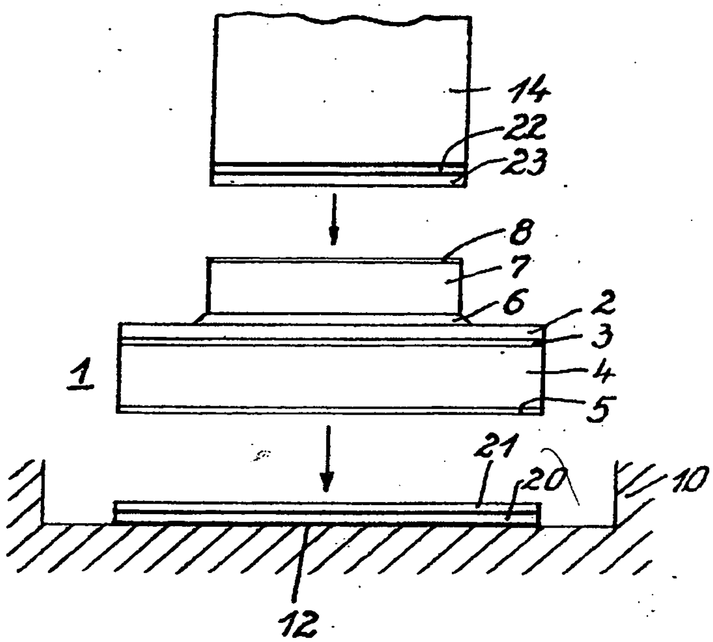

Figure 2